The Science of NanoSafety

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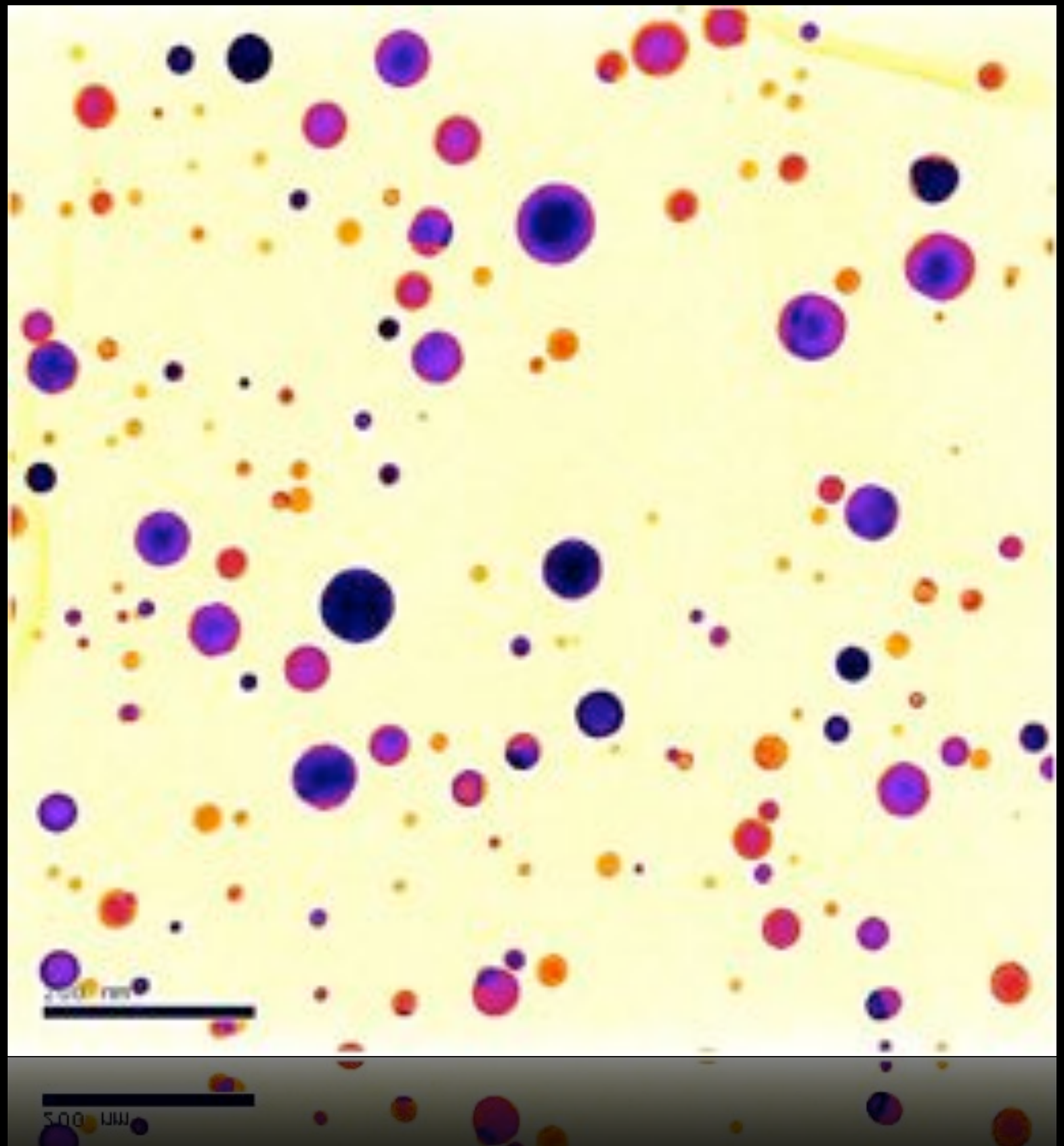
Woodrow Wilson International Center for Scholars (in partnership with the Pew Charitable Trusts)

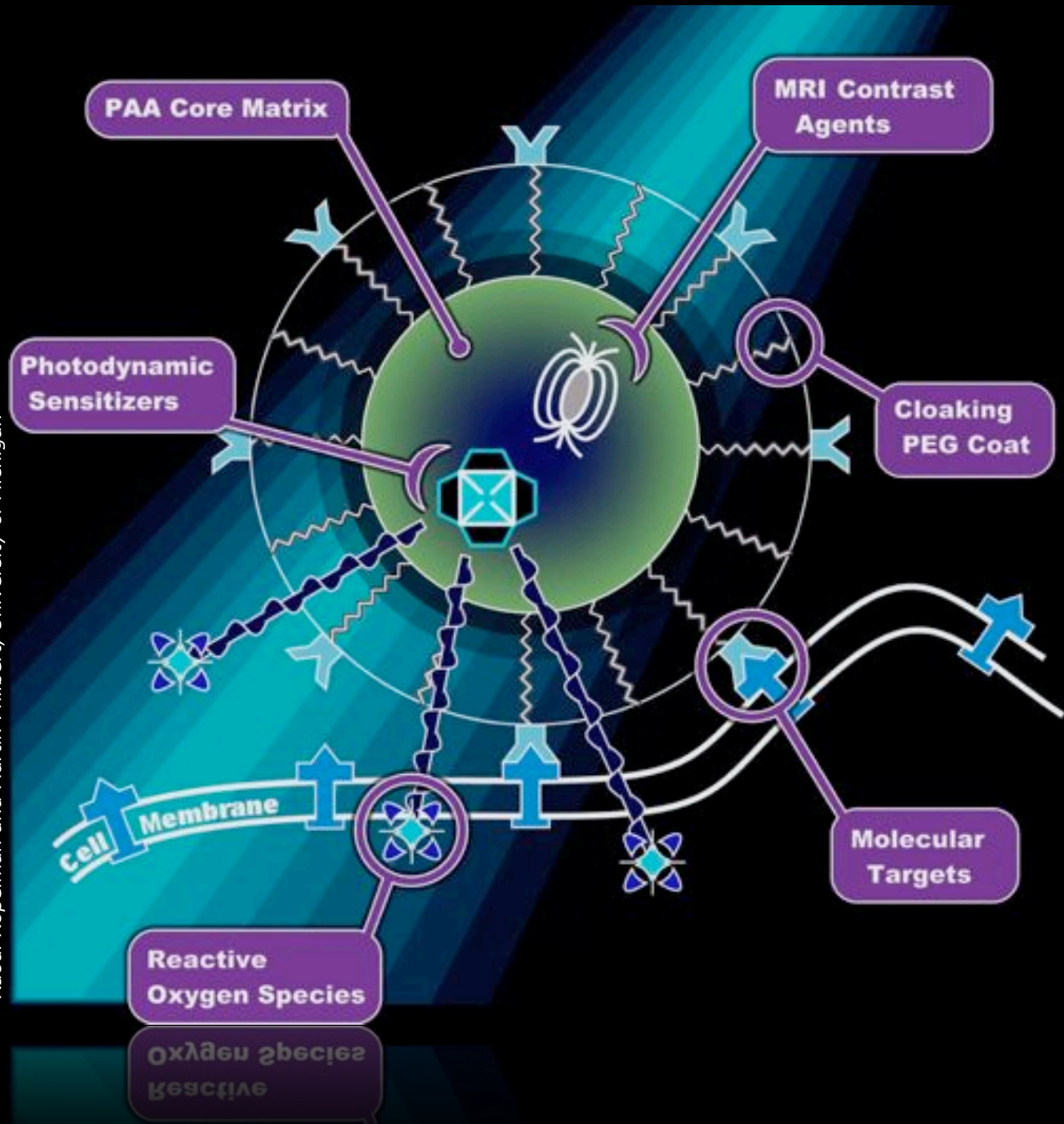
The art and science of building stuff that does stuff at the nanometer scale

Richard Smalley

Silver nanoparticles



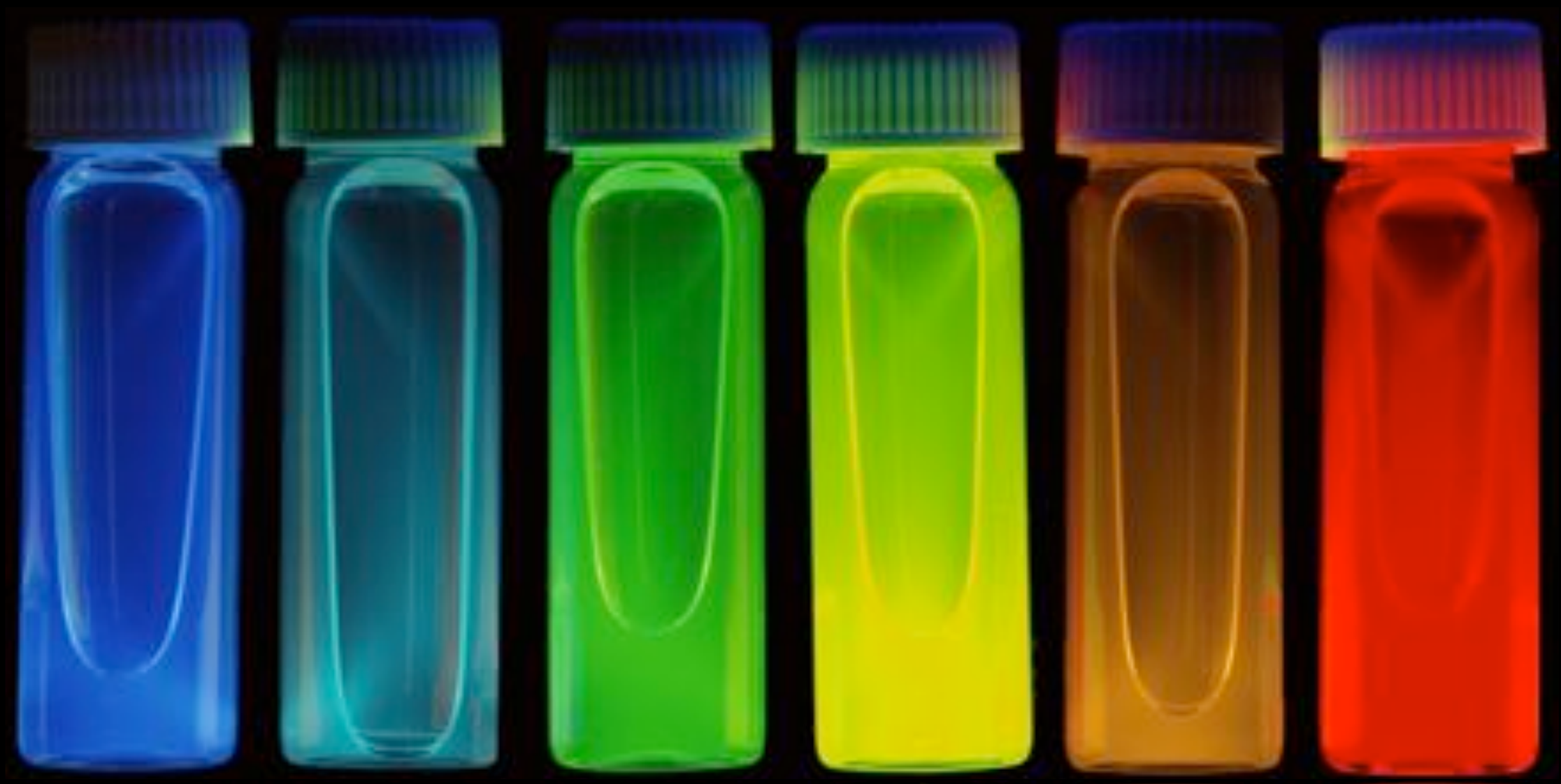
Smart nanoparticles



Raoul Kopelman and Martin Philbert, University of Michigan

Unique Quantum Properties

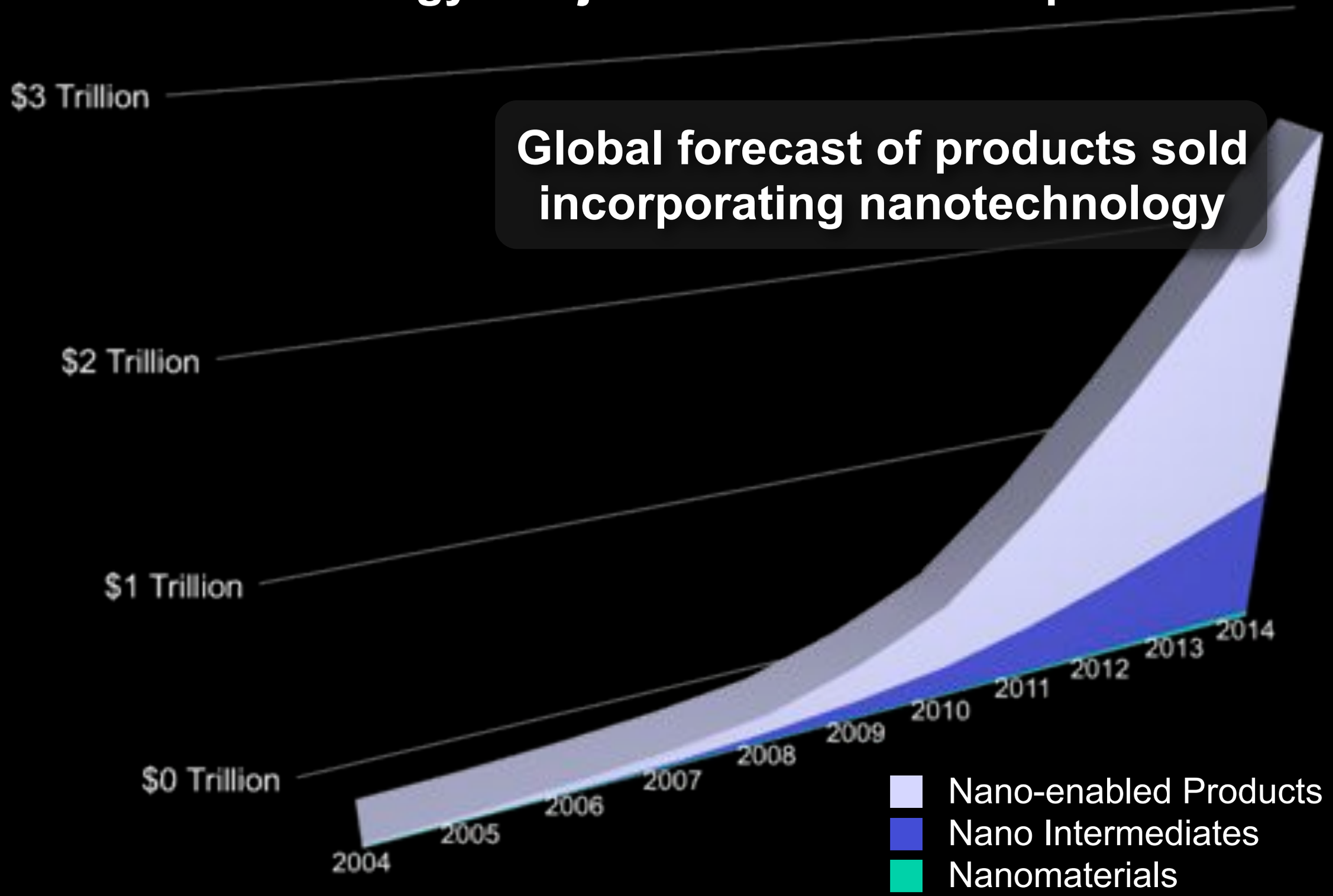
Quantum Dots - particle size determines fluorescence



Smaller particles → **Larger particles**

Commercial Benefits

Nanotechnology: Projected worth of nanoproducts



Source: 2004 Lux Research Report: “Sizing nanotechnology’s value chain”

Personal Benefits

Nanotechnology: The "I Wish" Technology

I wish my sunscreen wasn't so unsightly

I wish my socks didn't smell so much!

I wish my tennis racquet was lighter and stronger

I wish I could keep leftovers for longer, before they go off

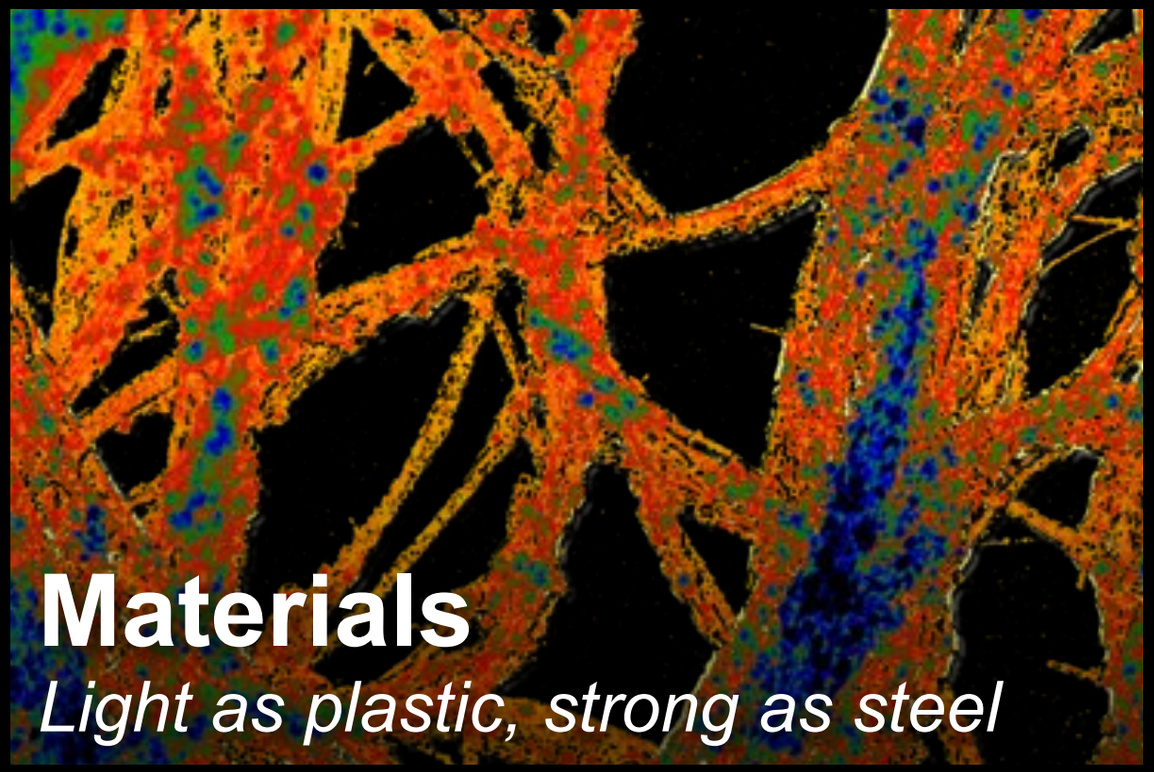
I wish spilt red wine would run off my pants without staining

I wish I could get more songs on my iPod

Over 500 listed nanotech consumer products: www.nanotechproject.org/consumerproducts

Societal Benefits

Nanotechnology: Solving the world's problems

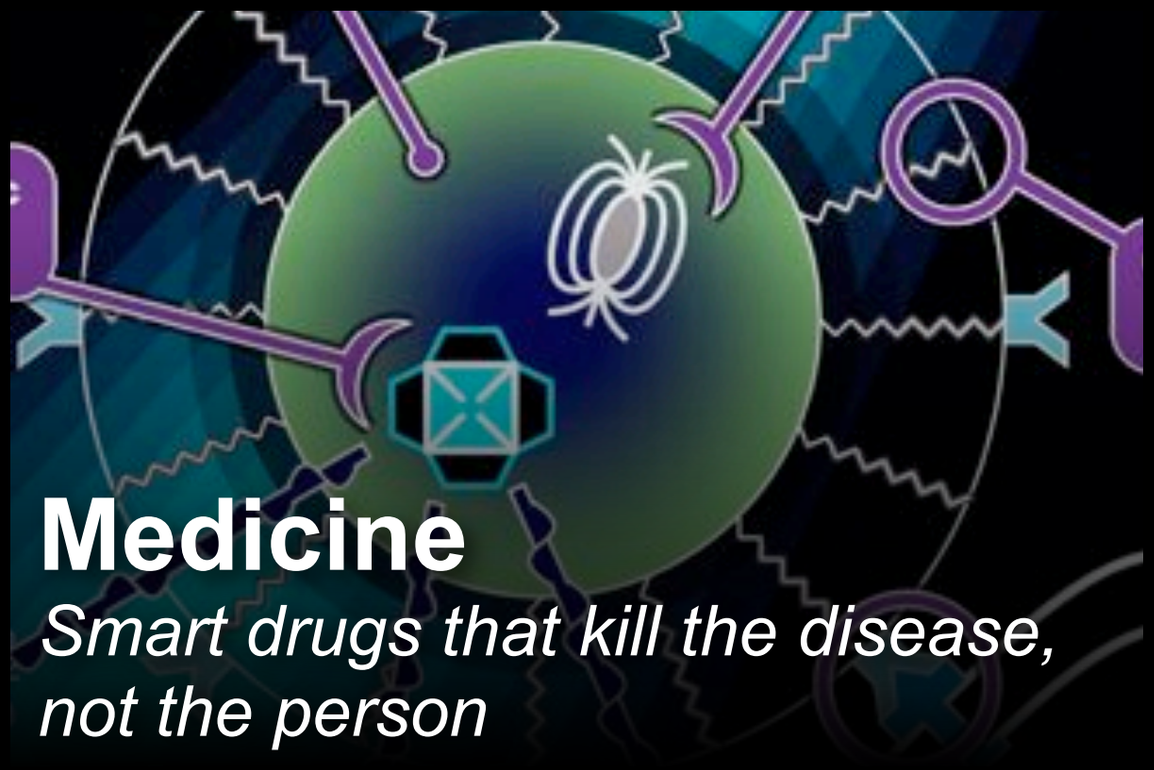


Materials

Light as plastic, strong as steel

Water

Clean water any time, any place



Medicine

Smart drugs that kill the disease, not the person

Energy

"PowerPlastic™ that converts light to energy - anywhere"

There’s no such thing as a free lunch, and nanotechnology is no exception

Developing sustainable nanotechnologies

The Three R's:

RISK

RESPONSE

REGULATION

RISK

...of causing harm to humans
and the environment

Nanotech Risks: An Industry Perspective

Corporation:

"We've cancelled several projects because of a lack of EHS information from the supplier"

Corporation

"We've stopped development where costs were too high to ensure no exposure or risk... It's quite complicated; we can't set decision points today"

Startup:

"Almost every time we talk with a company that will incorporate our material into products, EHS is one of the most important topics... Compared to companies that don't have this data, it puts us ahead of the curve ..."

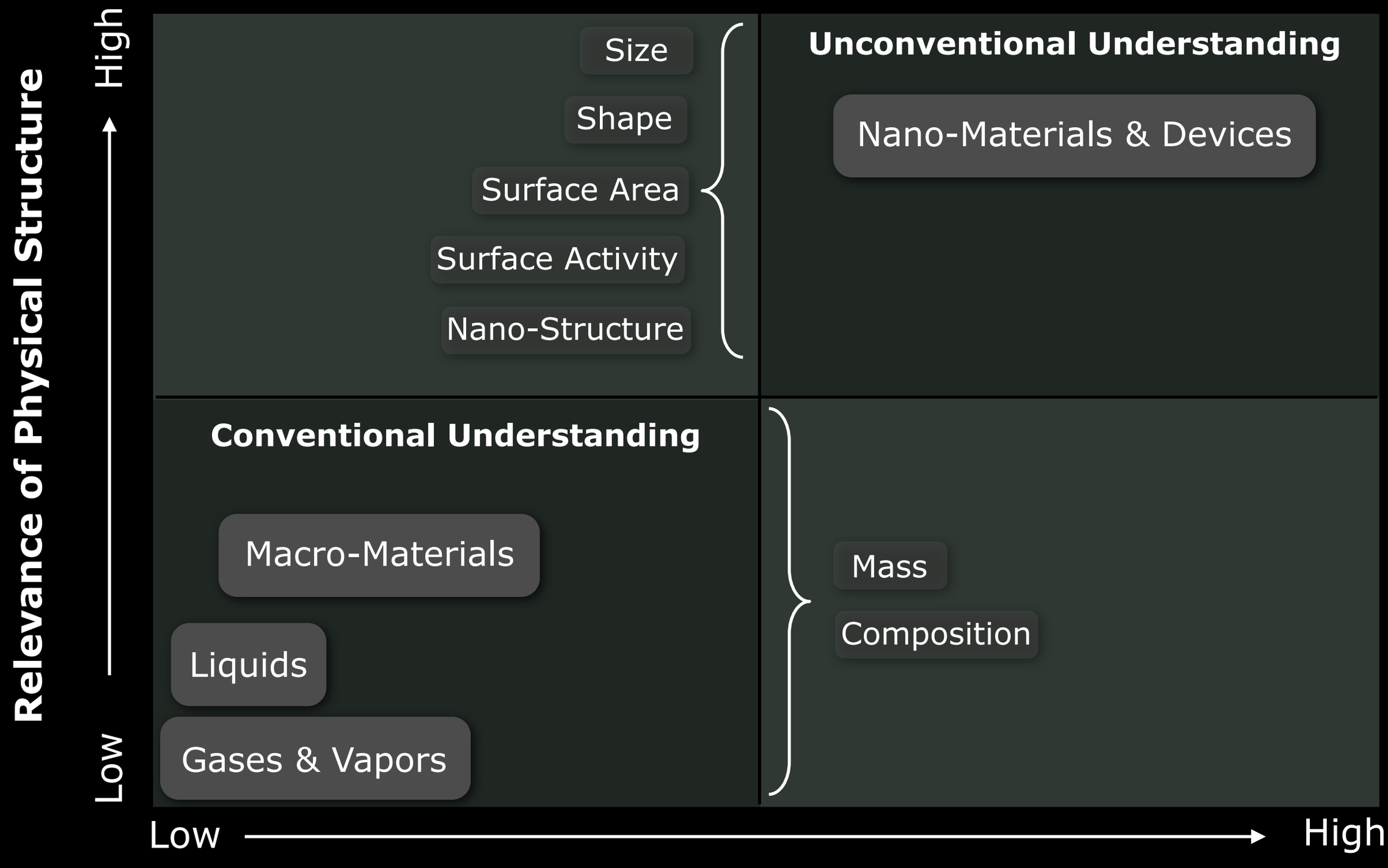
Source: Taking action on nanotech environmental, health and safety risks. Lux Research. May 2006

Nano-ZnO: One chemistry, many shapes

Courtesy of Prof. Z.L. Wang, Georgia Tech

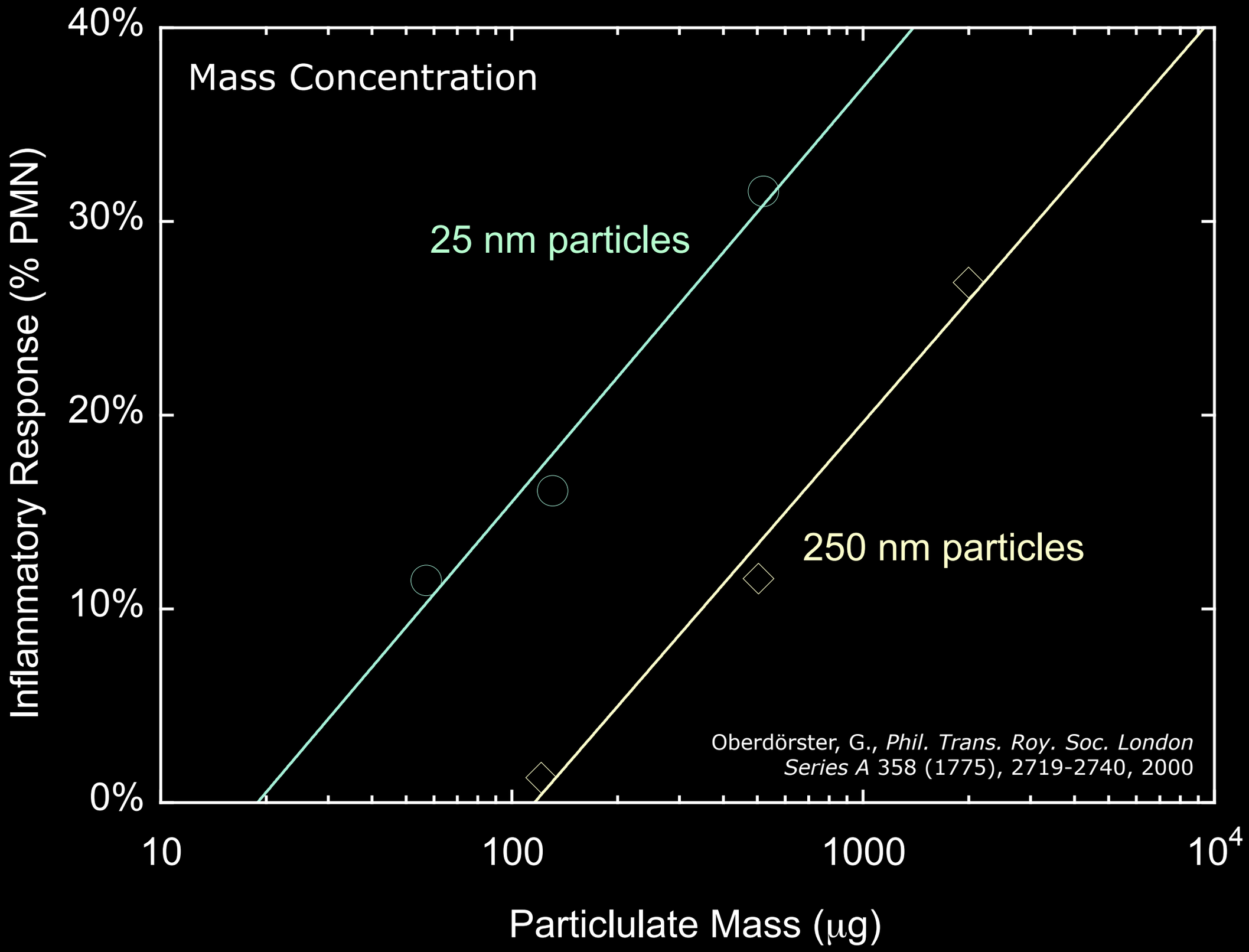
A thought experiment

The potential significance of structure on nanomaterial impact



Nano is no respecter of conventional paradigms

TiO2 particles in rats



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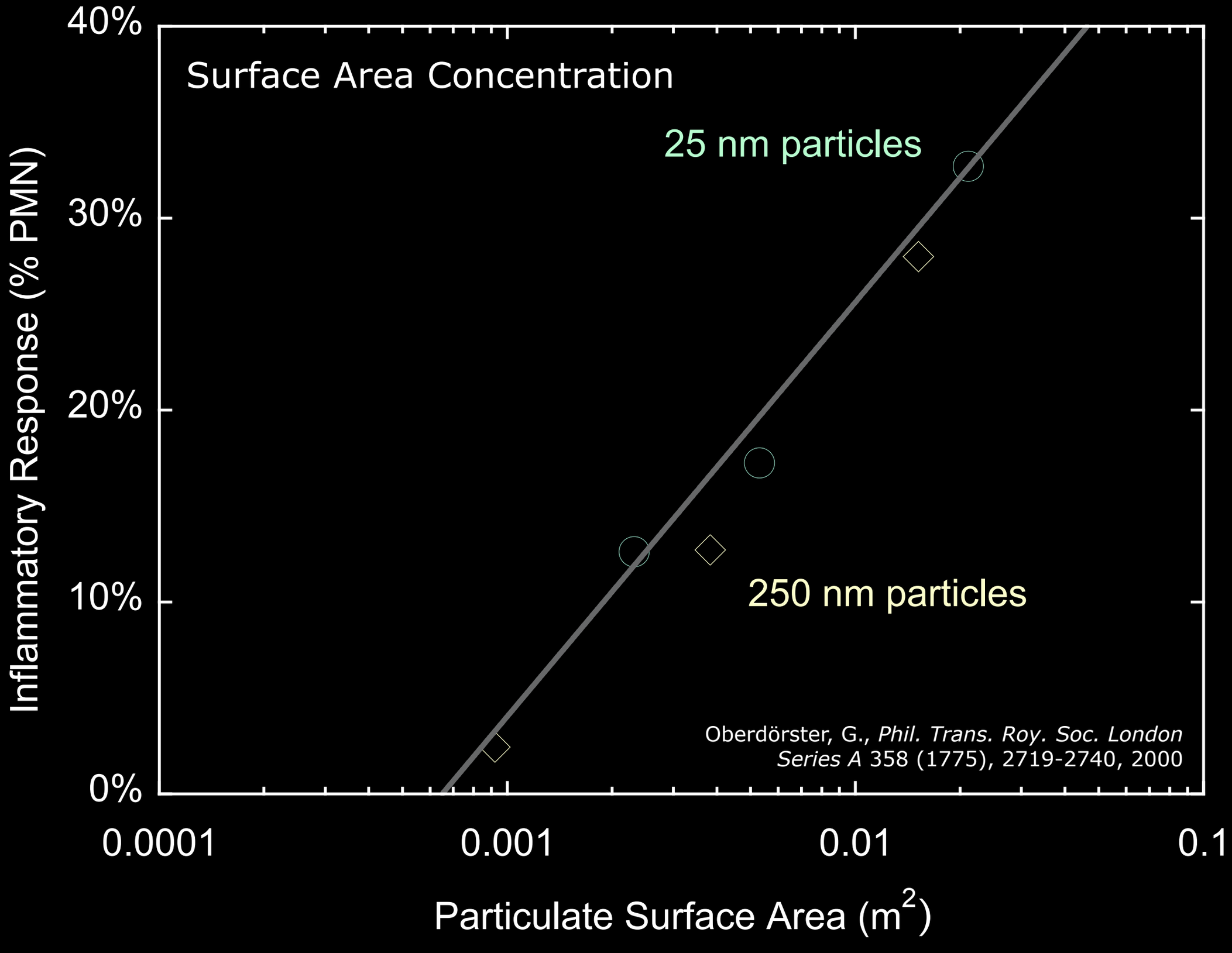
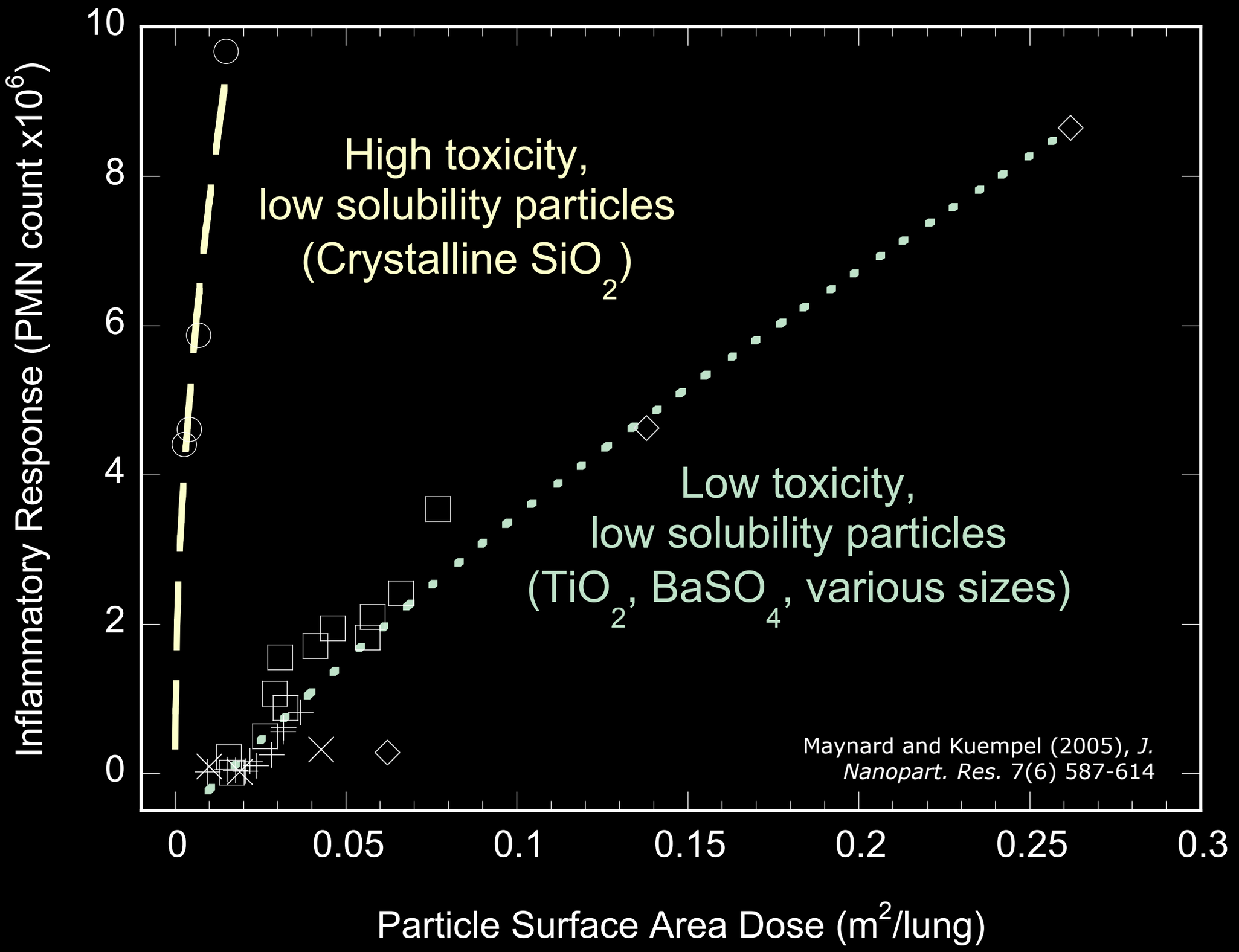


Nano is no respecter of conventional paradigms

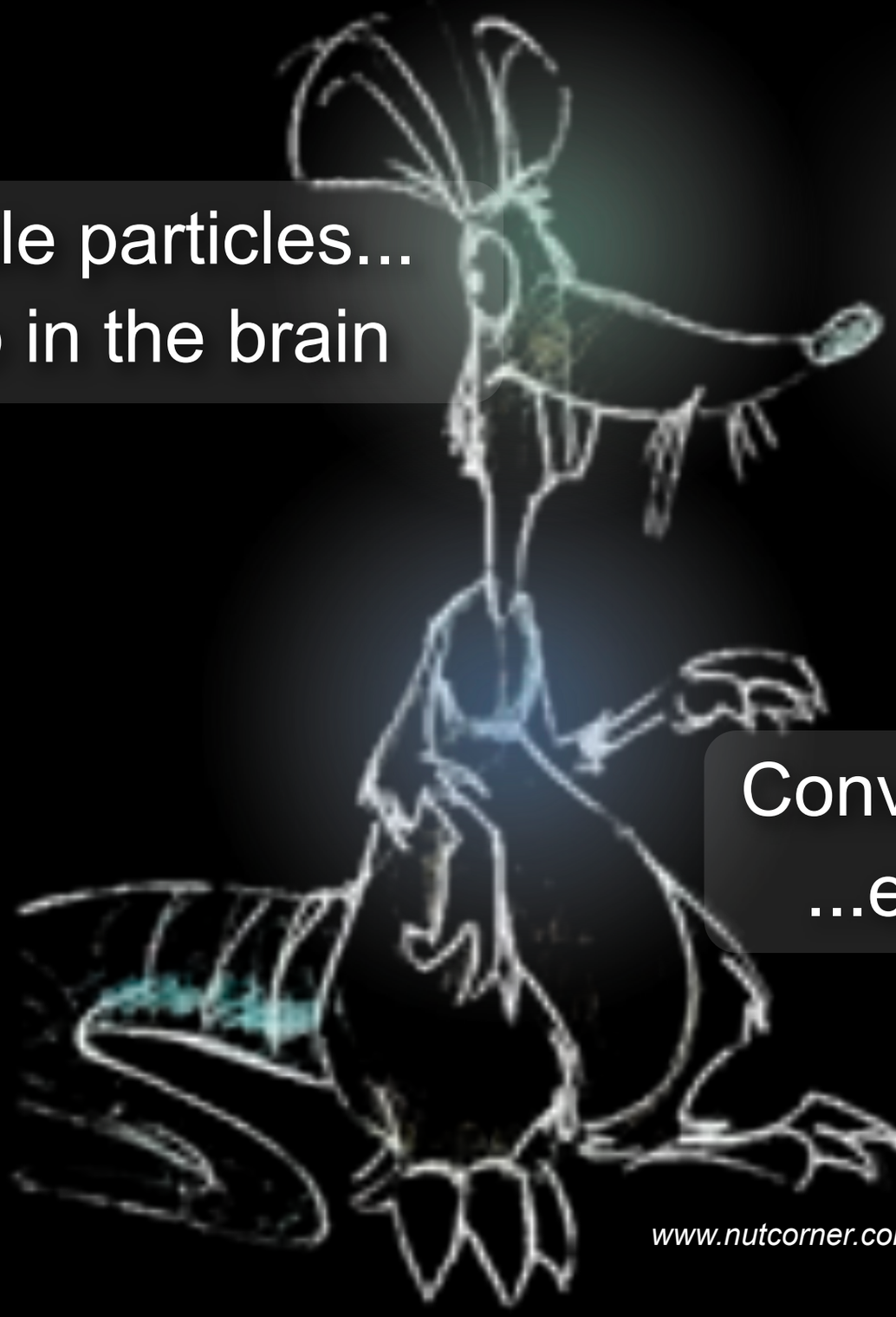
Relevance of surface area and chemistry - Instillation in rats



Nano gets to the places other technologies can’t reach

Translocation following inhalation - Nose to Brain

Nanoscale particles...
...end up in the brain



Conventional particles...
...end up in the lungs

www.nutcorner.com/drawing/rat.htm

(Based on Oberdörster, G., *et al. (2004)*, *Inhal. Toxicol.* 16 (6-7), 437-445)

Nano gets to the places other technologies can't reach

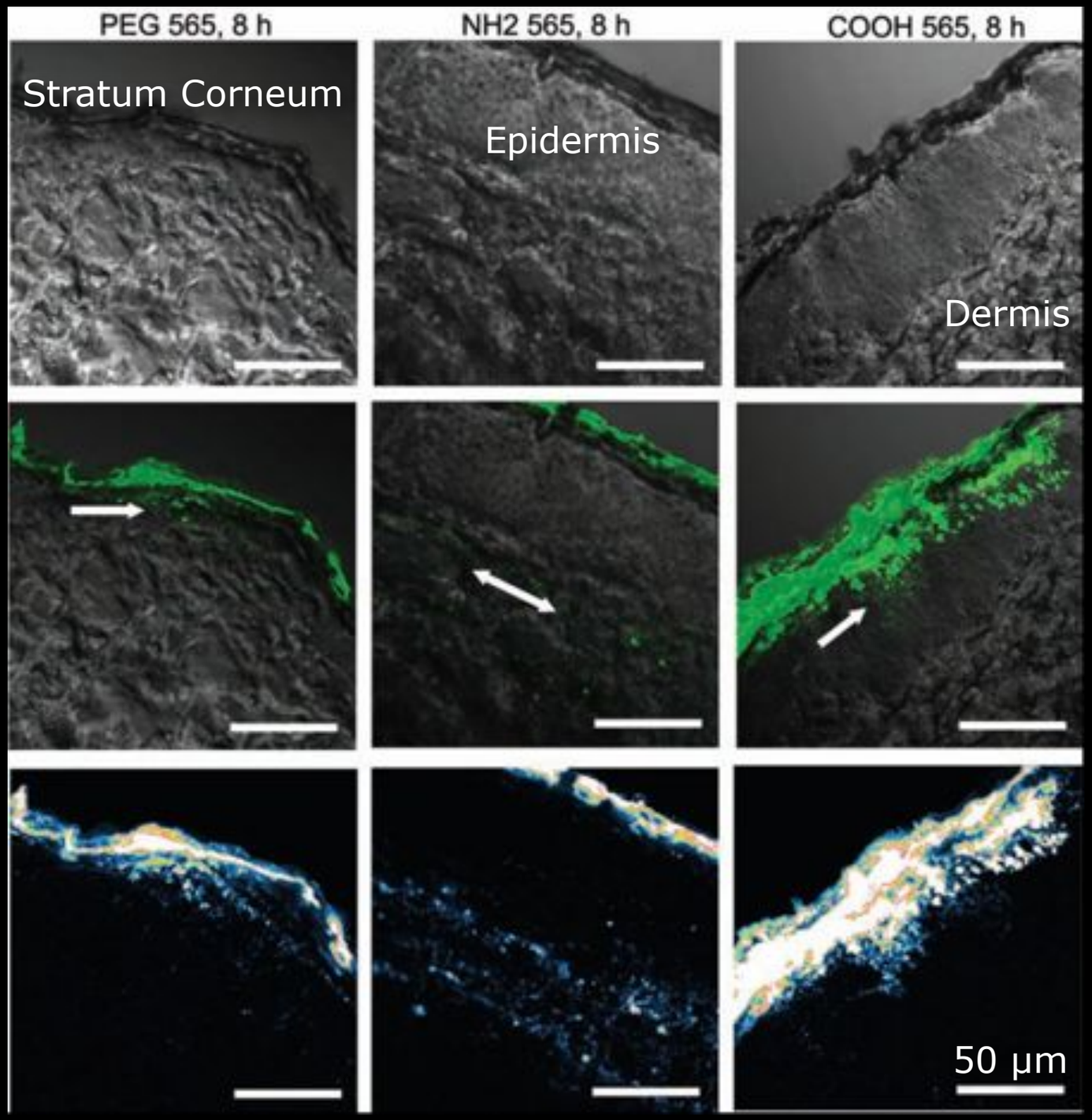
Possible penetration through the skin

Neutral | Cationic | Anionic

Confocal Scanning Microscope images

Quantum Dot fluorescence channel

Fluorescence intensity scan

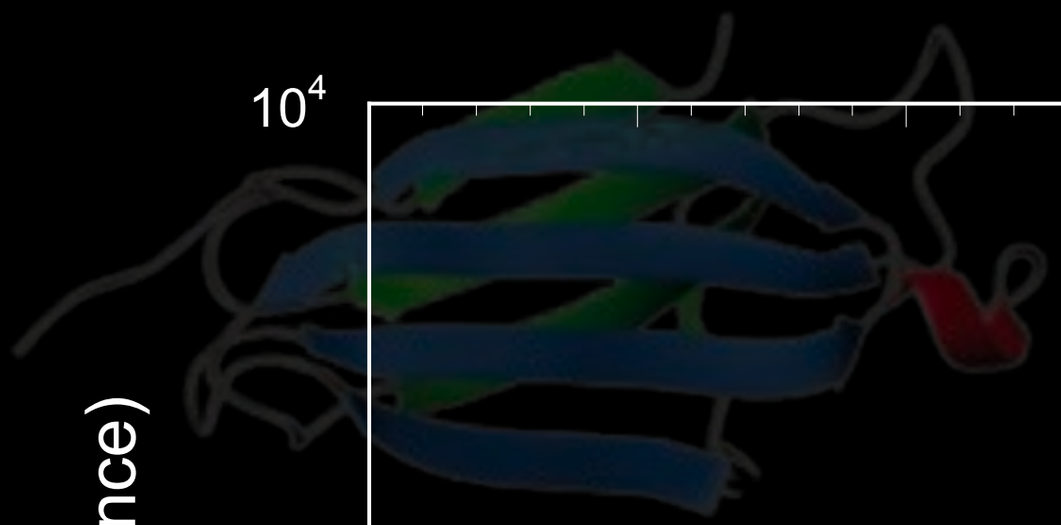


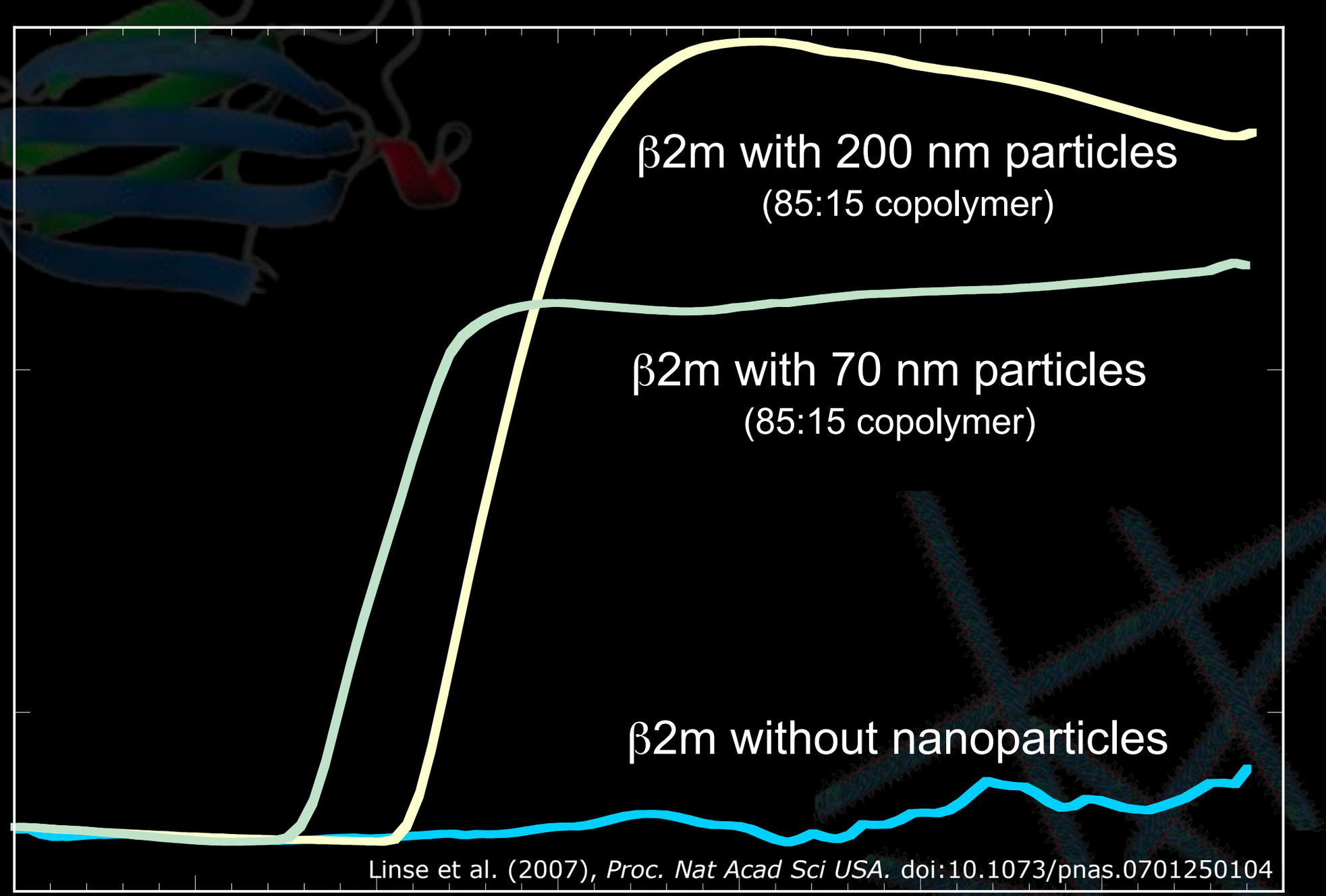
4.6 nm spherical Quantum dots in porcine skin flow-through cell

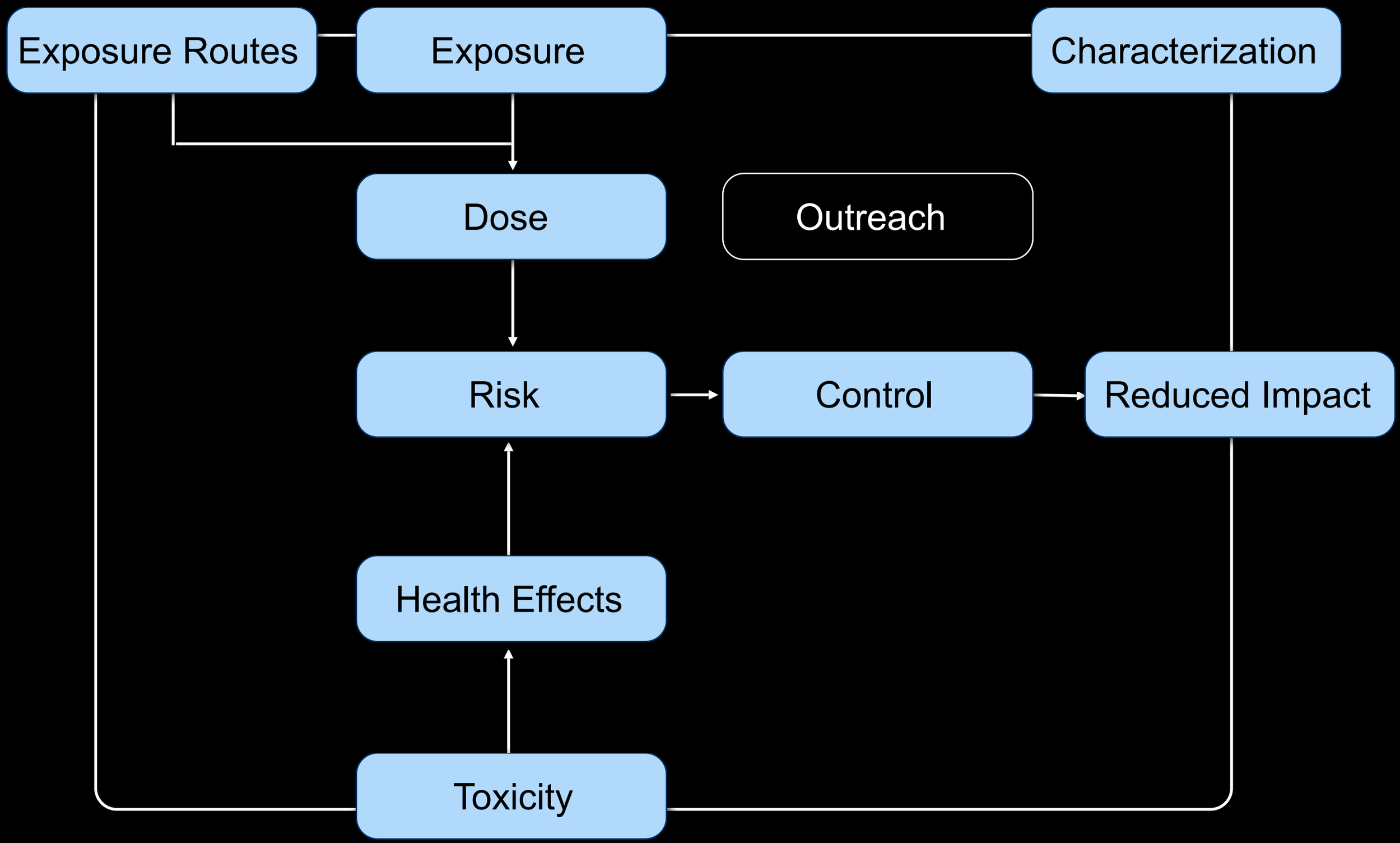
Ryman-Rasmussen, J. P., J. E. Riviere and N. A. Monteiro-Riviere (2006). Tox. Sci. ToxSci Advanced Access: Published January 27 2006

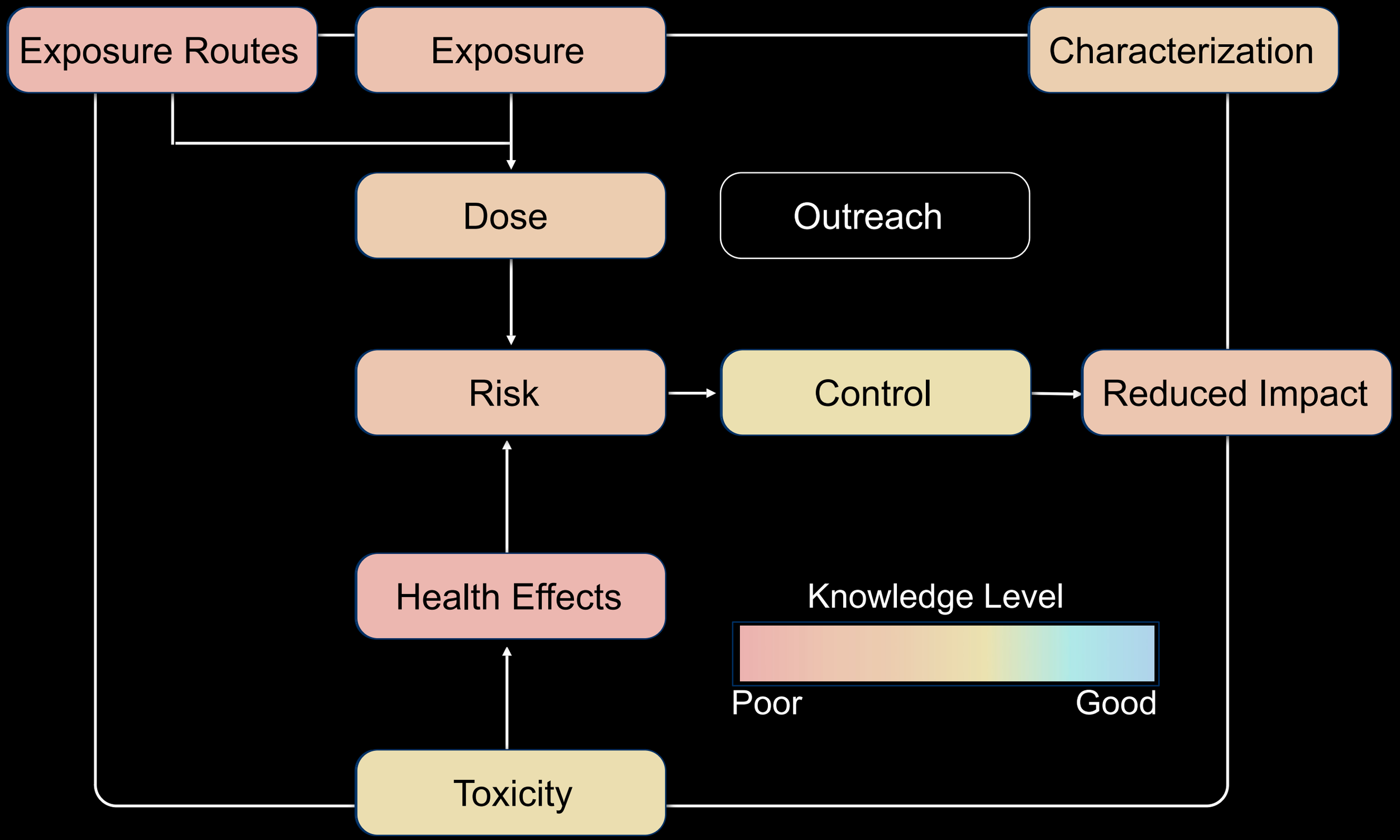
Nano interferes with biology at the nano scale

Stimulated fibrillation of beta-2 microgobulin






Exposure Routes
Exposure
Characterization
Dose
Outreach
Risk
Control
Reduced Impact
Health Effects
Toxicity

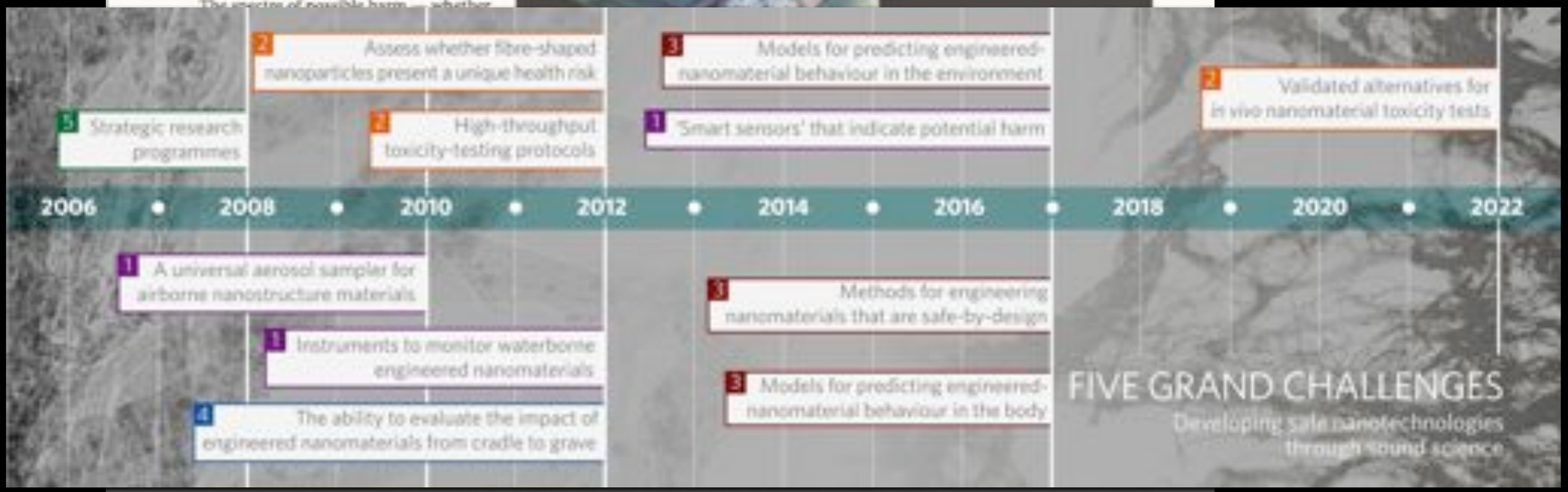

Exposure Routes
Exposure
Characterization
Dose
Outreach
Risk
Control
Reduced Impact
Health Effects
Knowledge Level
Poor
Good
Toxicity

COMMENTARY

Safe handling of nanotechnology

The pursuit of responsible nanotechnologies can be tackled through a series of grand challenges, argue **Andrew D. Maynard** and his co-authors.

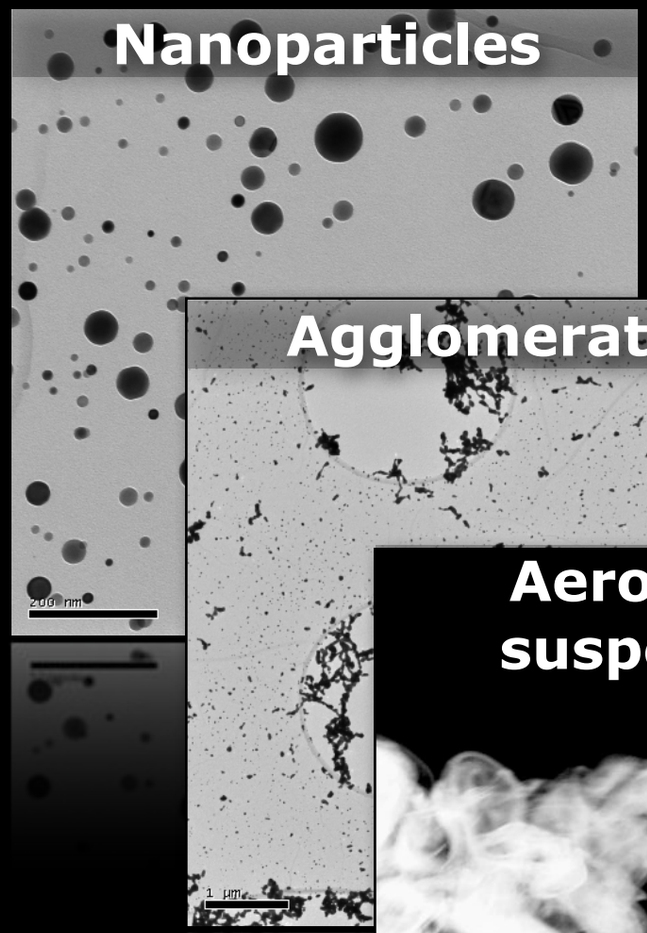
When the physicist and Nobel laureate Richard Feynman challenged the science community to think small in his 1959 lecture 'There's Plenty of Room at the Bottom', he planted the seeds of a new era in science and technology. Nanotechnology, which is about controlling matter at near-atomic scales to produce unique or enhanced materials, products and devices, is now maturing rapidly with more than 300 claimed nanotechnology products already on the market[1]. Yet concerns have been raised that the very properties of nanostructured materials that make them so attractive could potentially lead to unforeseen health or environmental hazards[2].

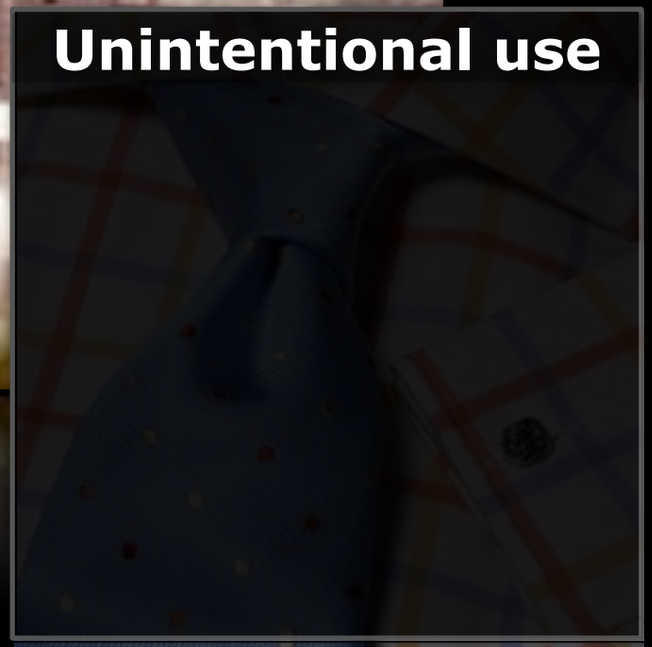


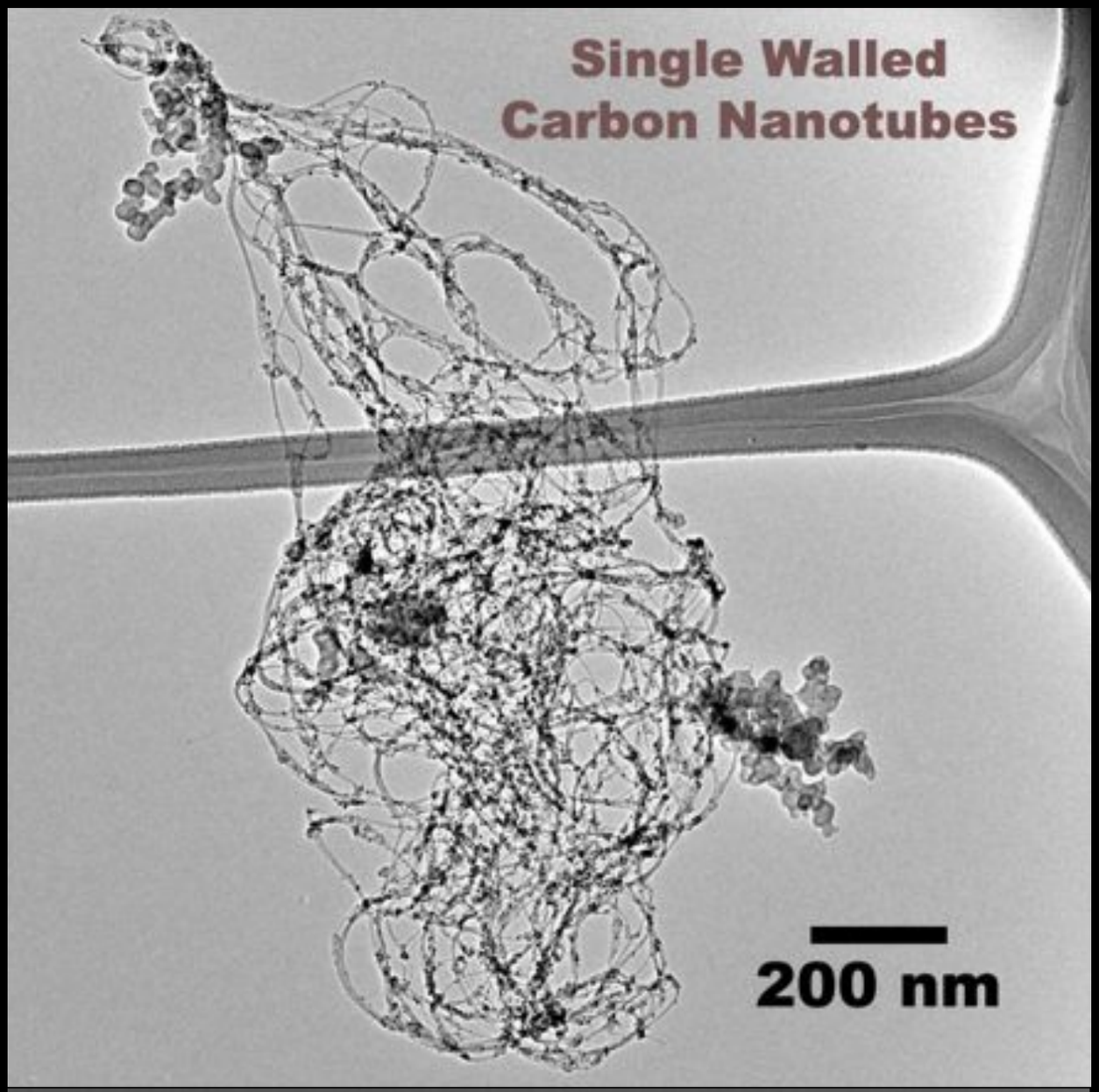
Nature Vol. 444/16 November 2006

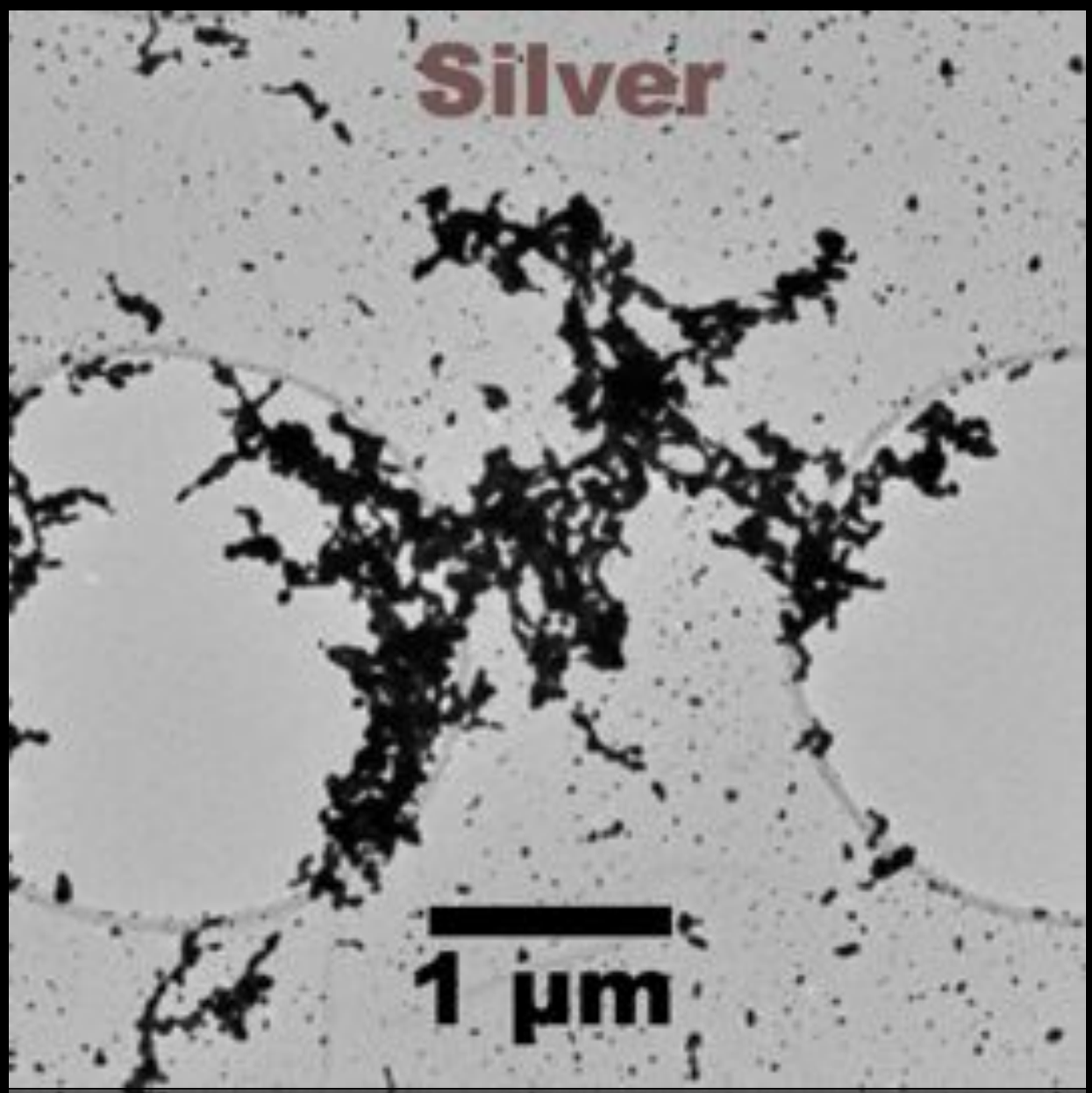
Setting Boundaries

Engineered nanomaterials which potentially present new challenges






Single Walled
Carbon Nanotubes
200 nm


Silver
1 µm

Estimated time for nanoparticles to increase in diameter by a factor of 10, through agglomeration

Particle Concentration (particles/cm^3)

10^{15}

10^{13}

10^{11}

10^{9}

10^{7}

10^{5}

1000

1 second

1 minute

1 hour

1 day

1 year

Gas-phase nanoparticle synthesis

Reactor leak

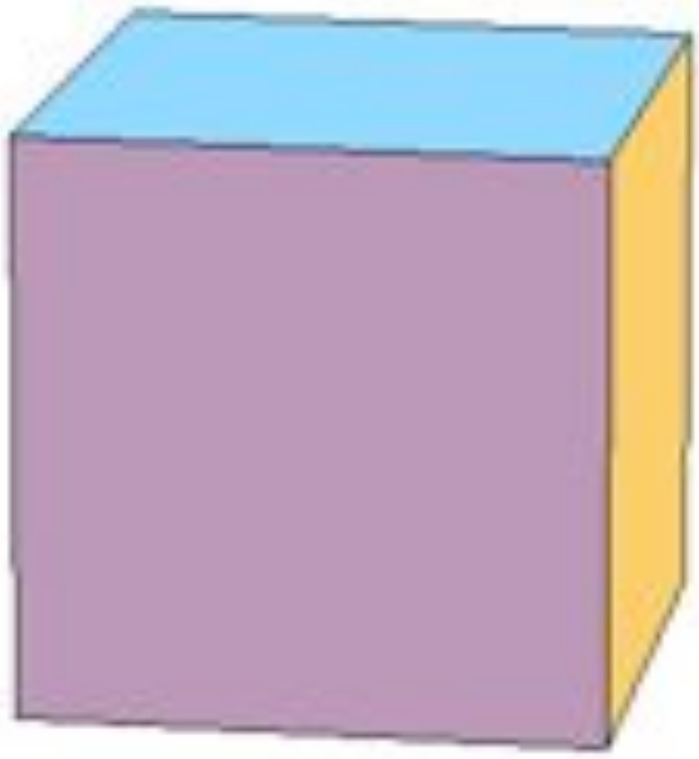
Busy traffic, or not-too-dirty workplace

Clean office or workplace

www.safenano.org

Time

Same Mass



Measuring exposure

Mass

Portable devices are available
Very limited nano-specificity

Number

Portable devices are available
Nano-sensitive, but not nano-specific

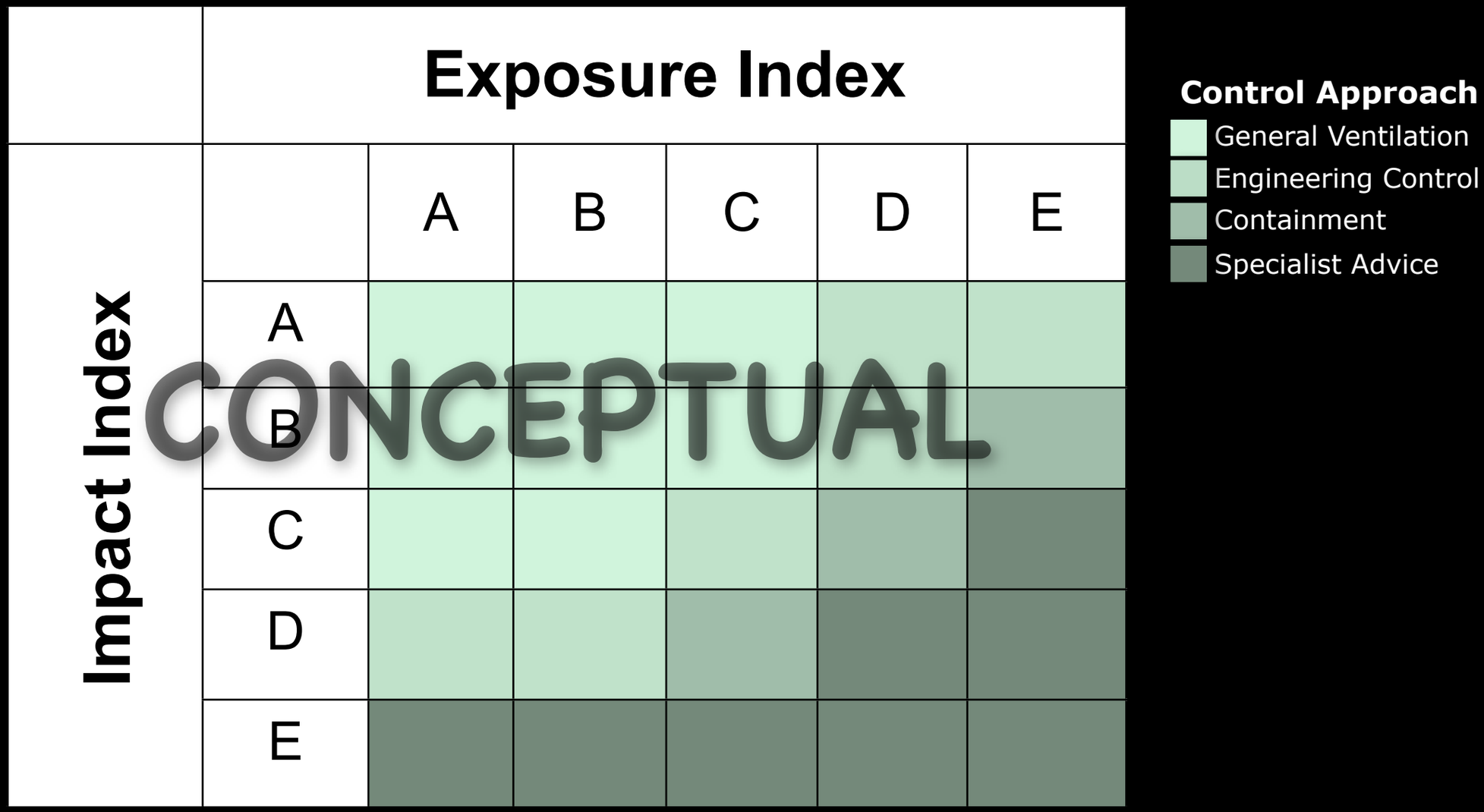
Surface Area

Portable devices are available
Method needs further development

Maynard and Aitken (2007), Nanotoxicology

Exposure Management

Can Expert Control Banding be used?



Exposure Index

‘Dustiness’
Amount Used

Impact Index

Bulk hazard
Surface Area
Surface Activity
Shape
Size

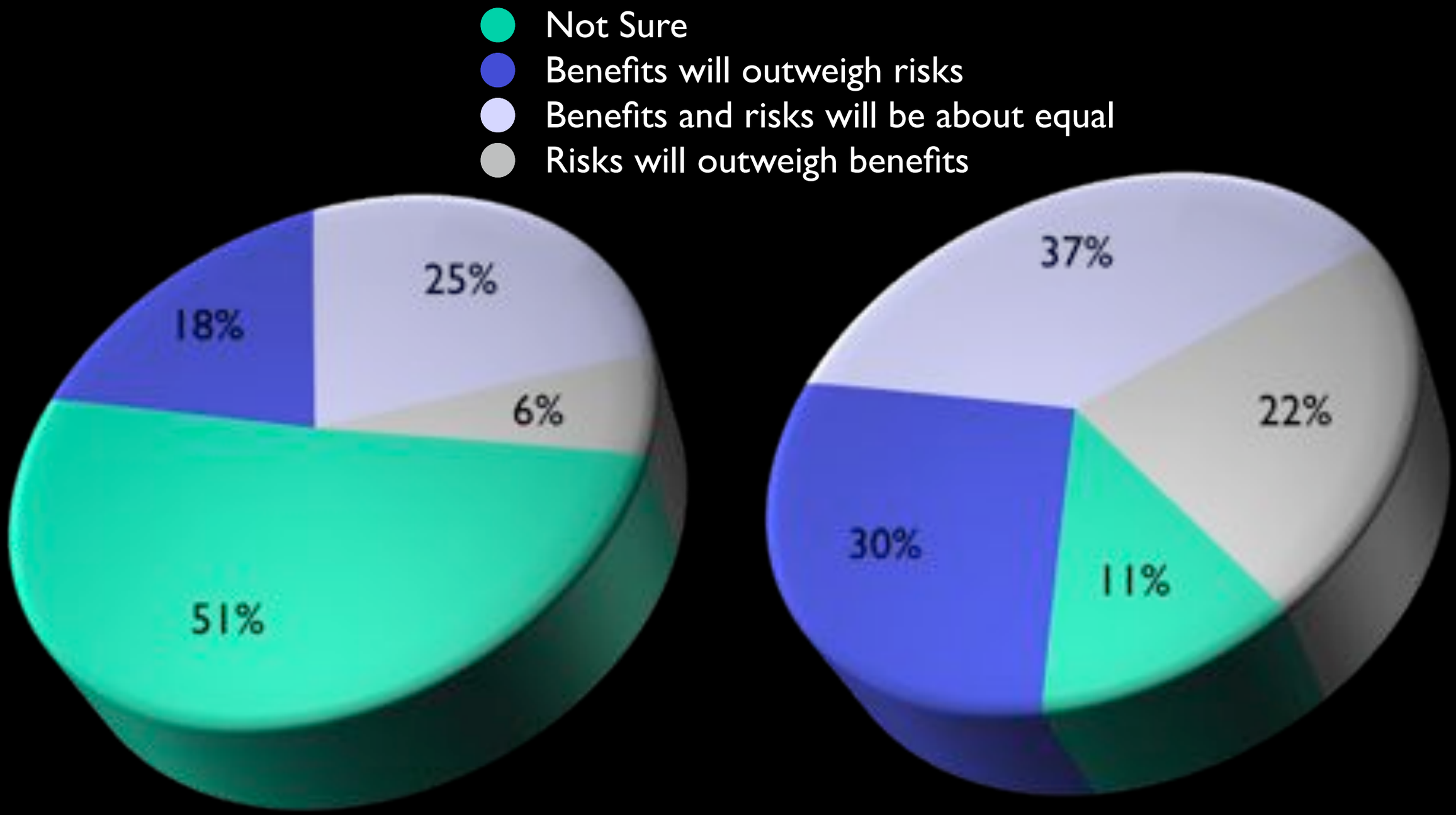
RESPONSE

...of potential users and
“beneficiaries”

www.chicagothong.org

Topless Humans Organized for Natural Genetics (THONG)

Public Opinion Poll: Attitudes Towards Nanotechnology



Initial impressions

Informed impressions

1014 adults polled

Hart Research Associated, published September 2007
www.nanotechproject.org/138

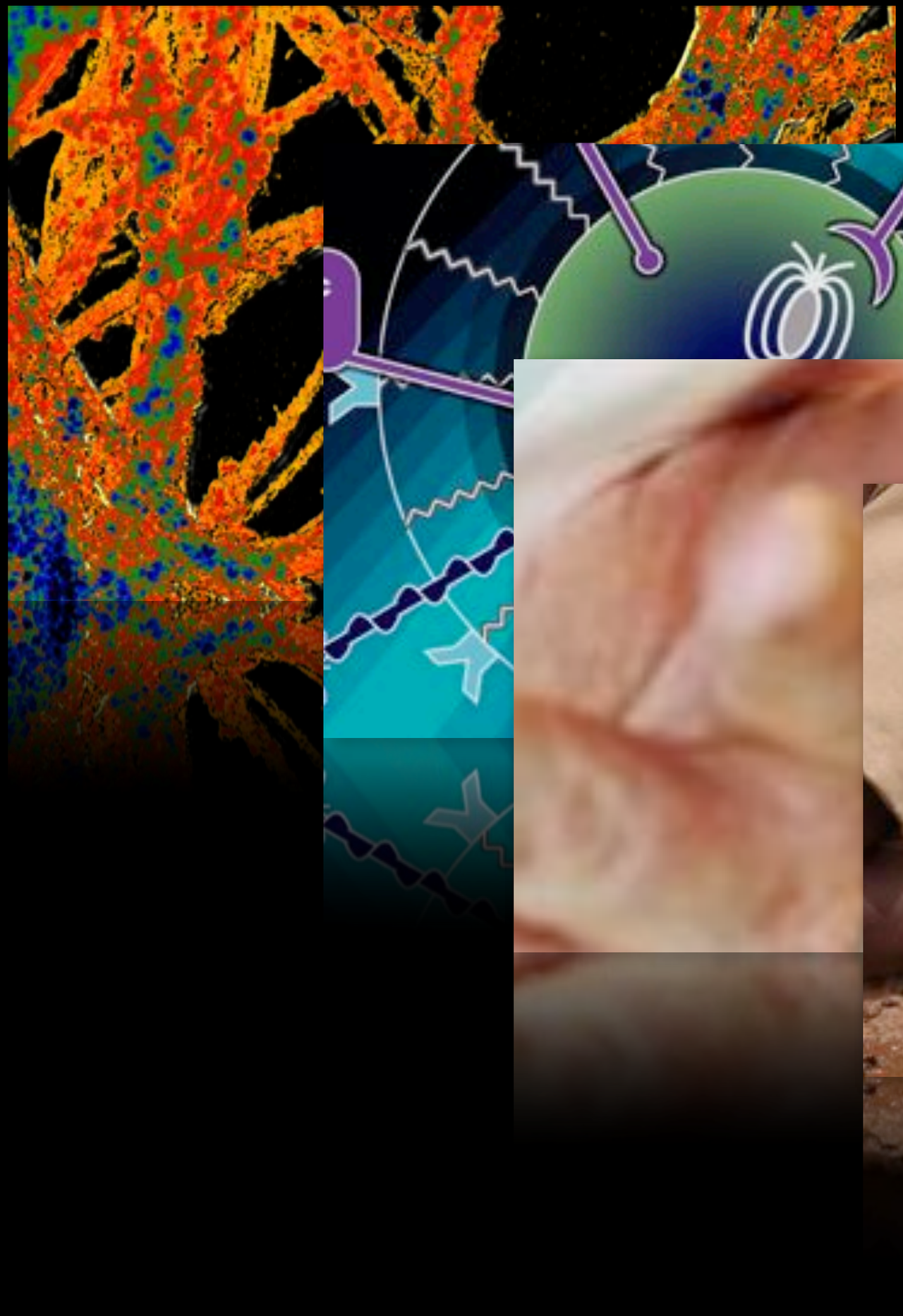
REGULATION

Avoiding undue risk through appropriate oversight

Would you “regulate” these products in the same way?

Smart Science

Underpinning the success of nanotechnology with multi-way conversations between scientists, policy-makers, producers and end users



Further Reading

Maynard, A. D. and D. Y. H. Pui, Eds. (2007). Nanoparticles and Occupational Health. Dortrecht, Netherlands, Springer.

Maynard, A. D., R. J. Aitken, T. Butz, V. Colvin, K. Donaldson, G. Oberdörster, M. A. Philbert, J. Ryan, A. Seaton, V. Stone, S. S. Tinkle, L. Tran, N. J. Walker and D. B. Warheit (2006). Safe handling of nanotechnology. Nature 444(16): 267-269.

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Maynard, A. D. & Kuempel, E. D. Airborne nanostructured particles and occupational health. Journal Of Nanoparticle Research 7, 587-614 (2005). Available free online. DOI:10.1007/s11051-005-6770-9

Maynard, A. D. and Aitken, R. J. (2007). Assessing exposure to airborne nanomaterials: Current abilities and future requirements. Nanotoxicology 1:26-41.

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